Impact Condition of Safety Performance Evaluation for Longitudinal Barriers of SMART Highway

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Abstract

To minimize the degree of damage for the SMART highway's punctuality and safety after car-barrier collisions, the impact condition for longitudinal barriers of SMART highway was determined to be quite larger than the existing maximum impact condition. The impact condition consists of impact vehicles, impact velocities, and impact angles. To consider the occupant safety of passenger cars as much as possible, a small car with high risk during impact was selected as the impact vehicle for the evaluation of occupant risk. The impact velocity was determined to be 20 % larger than the existing maximum impact velocity in order to include accident impact velocities as much as possible. The impact angle was determined to include most of expected accident impact angles. Computer simulations using various impact conditions were conducted for the existing domestic highest-performance medium and roadside barrier. How the suggested impact condition has an effect on the occupant safety was investigated. The existing domestic highest-performance medium and roadside barriers could not satisfy the suggested impact condition. New high-performance longitudinal barriers are required to minimize the degree of damage for the SMART highway's punctuality and safety after car-barrier collisions.

key words **:** Impact Condition, Longitudinal Barrier, Safety Performance Evaluation, Computer Simulation

1. Introduction

SMART highway, advancing the development of road construction technology according to the required changes for the future is the general research and development business for the road construction technology enhancing safety, mobility and convenience. For successful construction of SMART highway, the core technology related to roads infrastructure facilities in various fields must be supported. To minimize the degree of damage for the SMART highway's punctuality and safety after car-barrier collisions, the high effective and technical roadside safety facility must be developed by considering a special character of SMART highway. In order to achieve it, a standard of the roadside safety facility efficiency test for SMART highway must be established.

The roadside safety facilities installation in Korea are allowed for only facilities tested through full-scale crash test according to a guide of the "Installation and Management Guide for Roadside Safety Facility" [10] enacted in 2003. The guide for Korea allows the impact speed for securing occupants same as the road design speed, and the maximum impact speed is 100km/h.

In "NCHRP Report 350" [16], a guide of the United States roadside safety facility performance evaluation studying the roadside safety facility introduced the concept of "Forgiving Road" in 1950s. It suggests the impact speed as 100km/h in relation to the maximum road design speed, 110km/h.

In Europe, each country has developed and installed their own installation standards and evaluation, and after foundation of European Economic Community (EEC), European Committee for Normalization(CEN) conducted standardization of roadside safety facilities since 1990, and enacted "EN-1317" [1]. The maximum road design speed in Europe is 140km/h, specifically in Germany and Italy, and the maximum impact speed is 100km/h according to EN-1317. The reason of applying the impact speed, 100km/h in relation to the designed road speed as 140km/h is estimated as the application of the existing standard as it is due to lack of the systematic study of the roadside safety facility considering circumstances of high-speed driving rather than judge it with enough safety of the facility passed by the performance assessment.

The impact condition for the performance evaluation of the roadside safety facility to be installed on SMART highway allowing the road design speed, 120km/h is not prescribed in the domestic and international relevant standards. Thus, performance evaluation guide of a new roadside

safety facility considering the road design speed and driving characteristics of SMART highway is needed.

This study suggests the impact condition and its determination method for the roadside safety facility performance evaluation of SMART highway. Analyzing the results from simulations with various impact conditions for the existing domestic highest-performance longitudinal barriers, the author is evaluating the suggested impact condition and the effect on occupant safety.

2. Impact Condition of the Domestic and International Roadside Safety Facility

The roadside safety facility must satisfy safety for small car passengers and structural adequacy for heavy trucks simultaneously. Test results of the vehicle must coincide with the performance standard after the impact. The guide for domestic and international roadside safety facility performance evaluation is divided into the impact condition and performance evaluation standard for the result analysis of the impact test. The impact condition is divided into the safety evaluation for small car passengers and structural adequacy evaluation for heavy trucks.

2.1 Installation and Management Guide for Roadside Safety Facility

The domestic roadside safety facility performance evaluation standard is prescribed in "Installation and Management Guide for Roadside Safety Facility" [10]. The installation and management guide for roadside safety facility classifies the barriers in seven levels according to the performance level, and provides the impact condition according to the level. Among the seven levels, the impact condition for normal, higher and very high levels are shown in Table 1. The maximum impact test condition for the occupant safety is the impact vehicle of 1,300kg, with speed of 100km/h and angle equal to 20°. The maximum impact condition for the structural adequacy evaluation is the impact vehicle of 36,000kg, with a speed of 80km/h and angle equivalent to 15°.

Table 1. Impact Condition of Domestic Roadside Safety Facility

Performance Level		Impact Condition		
		Impact Vehicle (kg)	Impact Speed (km/h)	Impact Angle (deg.)
Normal	SB3	1300	100	20
		8000	80	15
Higher	SB5	1300	100	20
		14000	80	15
Very High	SB6	900	100	20
		25000	80	15
	SB7	900	100	20
		36000	80	15

-Normal Level: general highway section
-Higher Level: median barrier, bridges and roadside in danger,
-Very High Level: specific section such as an intersection

2.2 NCHRP Report 350

The U.S. roadside safety facility standard is prescribed in “NCHRP Report 350, Recommended Procedures for the Safety Performance Evaluations of Highway Features” [16]. NCHRP Report 350 classifies the performance level of the roadside safety facility into six levels, and suggests the impact condition of each level. In Table 2, the impact condition among the six levels according to normal, higher and very high levels are shown. In NCHRP Report 350, the maximum impact test condition for the occupant safety is the impact vehicle of 820kg, with a speed of 100km/h and angle of 15°, while the maximum impact condition for the structural adequacy evaluation is the impact vehicle of 36,000kg, speed of 80km/h and angle equal to 15°.

Table 2. Impact Condition of U.S. Roadside Safety Facility

Performance Level		Impact Condition			Remarks
		Impact Vehicle (kg)	Impact Speed (km/h)	Impact Angle (deg.)	
Normal	TL3	820	100	20	
		2000	100	25	
Higher	TL4	820	100	20	
		2000	100	25	optional
		8000	80	15	
Very High	TL5,6	820	100	20	
		2000	100	25	optional
		36000	80	15	

2.3 NCHRP Project 22-14

"NCHRP Project 22-14" [12] is the draft report update of NCHRP Report 350. The important changers are (1) increase of pickup truck weight from 2000kg to 2270kg, standard vehicle for evaluation of the structural adequacy of the safety facility, (2) increase of the impact vehicle from 820kg to 1100kg and angle from 20° to 25° as the impact condition of small car for occupant safety evaluation. In Table 3, among the six performance levels of NCHRP Project 22-14, its impact condition to standard, superior and specific levels are shown.

Table 3. Impact Condition of updated U.S. Roadside Safety Facility

Performance Level		Impact Condition			Remarks
		Impact Vehicle (kg)	Impact Speed (km/h)	Impact Angle (deg.)	
Normal	TL3	1100	100	25	
		2270	100	25	
Higher	TL4	1100	100	25	
		2270	100	25	optional
		8000	80	15	
Very High	TL5,6	1100	100	25	
		2270	100	25	optional
		36000	80	15	

2.4 EN-1317

Since 1990 in Europe, standardization of the roadside safety facility has been conducted, and "EN-1317" [1] has been used as the common standard. In EN-1317, the performance level of the facility is divided into four levels. In Table 4, its impact condition for normal, higher and very high levels are shown. In EN-1317, the maximum impact test condition for the occupant safety is the impact vehicle of 900kg, speed of 100km/h and angle equal to 20° and the maximum impact condition for the structural adequacy evaluation is the impact vehicle of 38,000kg, speed of 65km/h and angle of 20°.

Table 4. Impact Condition of Europe Roadside Safety Facility

Performance Level			Impact Condition		
			Impact Vehicle (kg)	Impact Speed (km/h)	Impact Angle (deg.)
Normal	N1	TB31	1,500	80	20
	N2	TB11	900	100	20
		TB32	1,500	110	20
Higher	H1	TB11	900	100	20
		TB42	10,000	70	15
	H2	TB11	900	100	20
		TB51	13,000	70	20
	H3	TB11	900	100	20
		TB61	16,000	80	20

Very High	H4a	TB11	900	100	20
		TB71	30,000	65	20
	H4b	TB11	900	100	20
		TB81	38,000	65	20

3. Impact Condition of SMART Highway Roadside Safety Facility

The impact condition for the full-scale crash test consists of impact vehicles, impact speed, and impact angles. The condition should be determined reflecting the worst condition according to the road's characteristics. In this research, in order to minimize the degree of damage for SMART highway's punctuality and safety after car-barrier collisions, the impact condition considers a high-speed environment.

3.1 Selection of Impact Vehicle

To consider the occupant safety of passenger car, a small car with a high risk during impact should be selected. In U.S. standards [16] a small car at the bottom 5% of the accumulated sales volume in mass is selected as the impact vehicle to secure the occupant safety as much as possible. Distribution of vehicle sales volume in mass from the lightest to the heaviest vehicles is used to determine the accumulated sales volume of vehicle in mass. In the draft report for update the U.S. standard, a small car at the bottom 2% of the accumulated sales volume in mass was selected [12]. In the Korean guide, a small car weighing 1,300kg is selected as most small cars with that weight are registered. The 1,300kg is the bottom 42.5% in domestic car sales in 2008 [7]. Though the 1,300kg car weight is successful in the occupant safety assessment, if a lighter car is impacted, the occupant safety cannot be guaranteed in great measure against U.S. or European standards.

The accumulated sales volume of the domestic cars weight for the last four years is less than the impact vehicles from the domestic and SMART highway standard is shown in Figure 1. The accumulated sales volume weighted less than the domestic standard, 1,300kg is 36.6% on the average. The accumulated sales volume weighted less than the SMART highway, 900kg is 7.5% on the average. The 7.5% sales volume presented by SMART highway is little larger than 5% of the accumulated vehicle sales volume in mass by the U.S. standard, but much less than 36.6% of the sales volume of the existing domestic standard. In addition, as the rate of the small cars below 900kg on the domestic highways, licensed as first class is 4.3% [5], the 7.5% sales volume by SMART highway is similar for the occupant safety compared with the 5% volume by the U.S. standard.

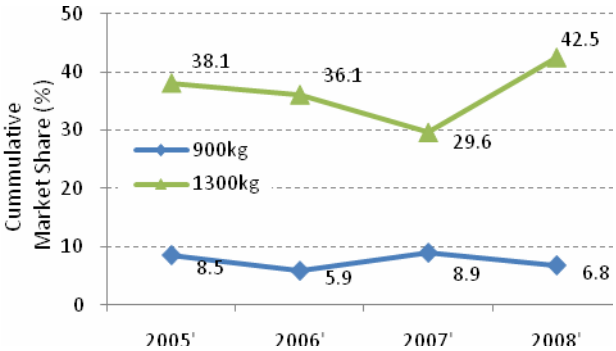

Figure 1. Domestic Car Sales Volume by Weight

In the draft report update for the U.S. standard, "Sport Utility Vehicles" (SUVs) as the impact vehicle is selected due to an increase of SUVs sales and high rollover frequencies after the collisions. In Korea, as shown in Table 5, SUVs sales volume exceeds 20% of car sales. A decrease of the sales volume in 2008 is regarded as momentary due to a sudden rise in gasoline price. In Figure 2, a rate of deaths due to passenger car accidents by details of cars in 2007 [9] is shown. For the death rate, SUVs exceed over 20% as well. Thus, SUVs are optionally used for the SMART highway impact vehicle in order to consider these matters.

The weight of SMART highway SUVs impact vehicle is decided as 2,000kg. It is equivalent of the average accumulated sales volume, 94.6% [5] for the last four years, and similar to U.S. standard, 95% [12].

Table 5. SUVs Sales Volume in the Whole Car Sales

Classification	2005'	2006'	2007'	2008'
SUVs Sales Volume(%)	27.4	23.6	26.7	18.0

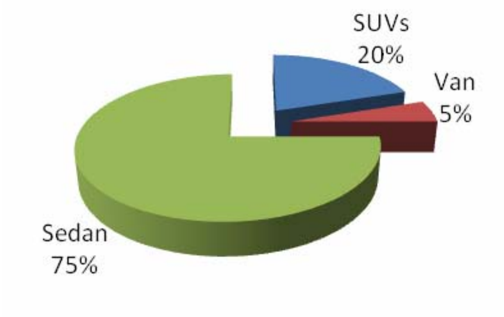

Figure 2. Rate of Deaths due to Passenger Car Accident by Details of Cars in 2007

To select heavy truck test vehicles, the author researched the truck sales volume by weight [5]. For the SMART highway Very High Level, the total weight of 36,000kg was selected corresponding to 97.8% of the average accumulated sales volume for the last four years. For the higher level, the 14,000kg vehicle weight was selected corresponding to 94.6%. For the normal level, the 8,000kg vehicle weight was selected corresponding to 89.8%. Such weights are the same weight as in the existing domestic guide.

3.2 Determination of Impact Speed

It is rational that the impact speed of the roadside safety facility performance evaluation is decided including the proper accumulated accident impact speed through research of the impact speed distribution from accidents by the intended speed of the road and cost-benefit analysis. The accident impact speed can be predicted by various evidences such as analysis of field trajectory data, road type, vehicle damage and injury severity. Various researches of the impact conditions of the single vehicle accident has been done [9] [11] [12] [13] [2], it is for the smaller road design speed than SMART highway. There is not any research of the highway accident impact speed in Korea.

Thus, in this research, the actual accident impact speed distribution [13] for the designed road speed, 110km/h was defined by a "gamma distribution function" in order to estimate the accident impact speed distribution over 120km/h for SMART highway designed road speed. Assuming the mean impact speed of gamma distribution function is in proportion with the intended speed, the method of extrapolation was applied for the distribution. From Figure 3 with the accumulated distribution of the actual accident impact speed for the planned road speed, the impact speed including 60% of the accumulated accident impact speed is about 100km/h, and the impact speed including 70% of the accumulated accident impact speed is about 110km/h. The maximum impact speed for the U.S. roadside safety facility performance evaluation was concluded as 100km/h to include 60% of the accumulated accident impact speed, and its speed is 90% of the planned road speed [3]. The domestic maximum impact speed is regulated same with the planned road speed, 100km/h. The accumulated distribution of the expected accident impact speed for the designed road speed, 120km/h and140km/h is shown in Figures 4 and 5. Table 6 shows the impact speed according to the rate of the accumulated accident impact speed by the planned road speed.

This research suggested the impact speed of the occupant safety evaluation from the SMART highway roadside safety facility as 120km/h. If the planned road speed, 120km/h is applied, it includes 70% of the accumulated accident impact speed, and in case of 140km/h, 60% of the accumulated accident impact speed is included. Moreover, if the SMART highway planned road speed is 120km/h, it corresponds with the domestic guide, impact speed for the occupant safety evaluation must be same as the planned road speed.

Considering the driving characteristics of heavy trucks, the heavy truck impact speed to evaluate the structural adequacy of the SMART highway roadside safety facility was suggested as 85km/h, 70% of the small car's impact speed.

3.3 Determination of Impact Angle

It is rational to determine the impact angle as confirmed from the impact speed through a wide range of the accident analysis. However, the impact angle has not been investigated in domestic accidents records, and its researches through analysis of roadside encroachment data do not exist at all.

Thus, the author analyzed the instances research of Europe [2] instead of data of the domestic accident instance since its road condition is similar to Korea. RISER Project (2005) established database by classifying the car accidents related to the roadside infrastructure facilities from the accident records of European countries. Figure 6 shows the accumulated impact angle distribution of RISER Project. Table 7 shows the rate of accumulated accident by angles from Figure 6. It appears that the impact angle 25° includes 98% of the accident impact angle. The impact angle for small cars was decided as 25° in order to include the accident impact angles as much as possible. In case of the heavy truck, the impact angle was decided as 15° considering cornering characteristics of heavy truck.

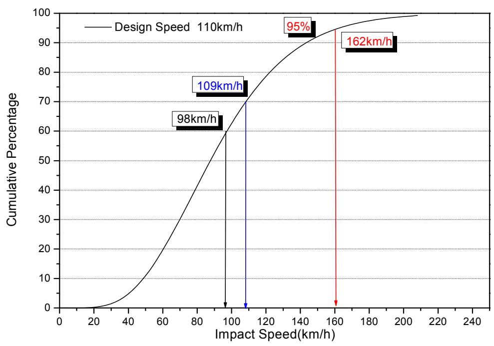

Figure 3. Accumulated Distribution of the Accident Impact Speed at the Designed Road Speed, 110km/h

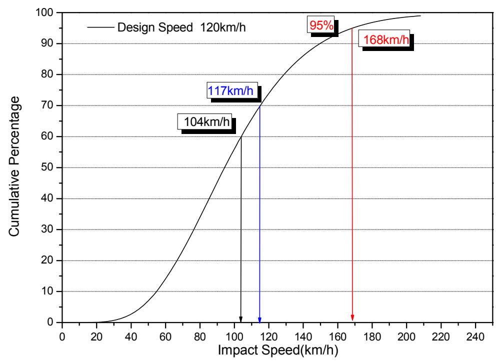

Figure 4. Expected Accumulated Distribution of the Accident Impact Speed at the Designed Road Speed, 120km/h

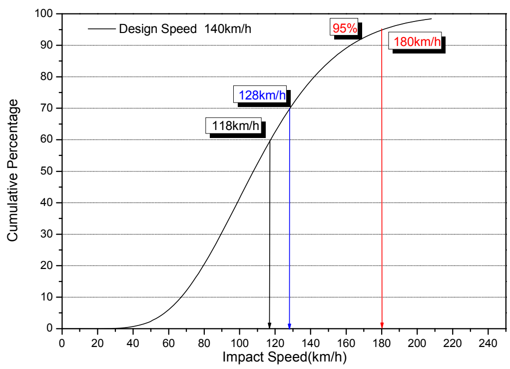

Figure 5. Expected Accumulated Distribution of the Accident Impact Speed at the Designed Road Speed, 140km/h

Table 6. Impact Speed of the Accumulated Accident by the Planned Road Speed

Planned Road Speed (km/h)	60%of Accumulated Accident Impact Speed(km/h)	70%of Accumulated Accident Impact Speed(km/h)	Impact Speed of SMART Highway (km/h)
113	98	109	120
120	104	117	
140	118	128	
160	138	149	

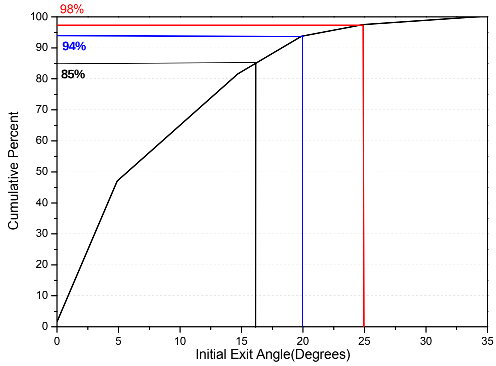

Figure 6. Accumulated Distribution of the Impact Angle

Table 7. Impact Angle According to the Rate of Accumulated Impact Angle

Accumulated Accident (%)	Impact Angle (deg.)	SMART Highway Impact Angle (deg.)
83	15	25
94	20	
98	25	

4. Impact Condition of SMART Highway Roadside Safety Facility Effect on Occupant Safety

Table 8 shows the impact condition for the performance evaluation of the SMART highway roadside safety facility. The condition is classified as normal, higher and very high level according to the road dangerousness. Maximum impact test condition for the occupant safety evaluation is 900kg for the impact vehicle, impact speed as 120km/h and impact angle as 25°. Maximum impact test condition for the structural adequacy is 36,000kg for the impact vehicle, impact speed as 85km/h and impact angle as 15°.

Table 8. Impact Condition of SMART Highway Roadside Safety Facility

Performance Level		Impact Condition			Remarks
		Impact Vehicle (kg)	Impact Speed (km/h)	Impact Angle (deg.)	
Normal	L1	900	120	25	
		2000	120	25	Optional
		8000	85	15	
Higher	L2	900	120	25	
		2000	120	25	Optional
		14000	85	15	
Very High	L3	900	120	25	
		2000	120	25	Optional
		36000	85	15	

- Normal Level: general highway section, small car/heavy truck division section
- Higher Level: dangerous section of central reservation, balustrade and roadside
- Very High Level: particular section such as an intersection

A simulation applying various impact conditions was conducted to evaluate the physical meaning and adequacy for the impact condition of the suggested SMART highway longitudinal barriers. For the analysis, the best performance facility was selected among barriers for the median and roadside in the domestic existing highest performance level. The selected barrier for the median and roadside are shown in Figures 7 and 8 respectively. The median barrier for the analysis is a model by Korea Highway Corporation that its height was increased from 810cm to 1270cm to improve the structural adequacy of the existing F type concrete median barrier. The roadside barrier for the analysis is a model with improved opening that consists of posts 2m apart strengthened by structural steel pipes and 2 leveled C type structural steel beam compared with the existing roadside barrier with W and Thrie type beams.

Figure 7. New-F Type Concrete Median Barrier for the Simulation

Figure 8. Open Type Roadside Barrier for the Simulation

The computer simulation used was LS-DYNA, 3D nonlinear dynamic analysis program, widely used for the analysis of the roadside safety facilities. The vehicle for the impact simulation was a Dodge NEON, Detailed Model [14] from NCAC shown in Figure 9 was used since domestic vehicle certified FEM models are few and developing vehicle model is very expensive. To obtain data of the vehicle's acceleration and angular speed, an ACCELEROMETER element was set on the center of gravity. The obtained data was used to calculate the occupant safety indexes by applying CFC 180 filter. The concrete barrier was modeled by using solid elements. The roadside barrier was modeled by using shell elements, and material property of SS400 structural steel was used. To model of interaction with the barrier and vehicle, the contact algorithm was applied to the contact surface.

For the verification of the analysis model, results [7] [8] of domestic full-scale crash test condition (vehicle mass of 1300kg, impact speed of 100km/h and impact angle of 20°) and simulation with the same impact conditions are compared as shown in Figure 10 and Table 9. Figure 10 presents the longitudinal velocity of the simulation and the full scale crash test and a good agreement on the results can be seen. Using these results and according to domestic standard [10], occupant safety indexes THIV (Theoretical Head Impact Velocity) values and PHD (Post-Impact Head Deceleration) values were determined and shown in Table 9. THIV is the impact velocity when the theoretical head's impacts against an inner car surface assuming the head as a free flying object and PHD is the minimum value of deceleration of the head upon contact on the inner car surface. From the maximum error of THIV and PHD values the occupant safety indexes from the simulation and full-scale crash test was under 3.2%, it is determined that the simulation model is similar with the actual impact vehicle. Impact condition for full-scale crash test and simulation are the same, except for impact vehicles. As previously mentioned, the design standards of domestic and international roadside safety facility, only the impact vehicle weight is prescribed for the impact test, and specific vehicle type is not prescribed. Through comparison of the results from the full-scale crash tests and simulations, it is realized that the change in vehicle type does not affect the simulation result.

Figure 9. Dodge NEON Car Model

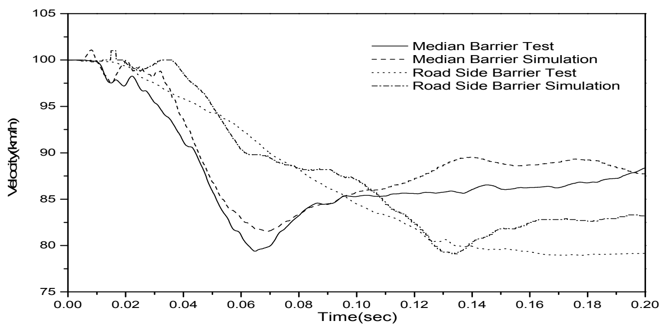

Figure 10. Longitudinal Velocity of Simulation and Crash Test

Table 9. Occupant Safety Indexes Full-Scale Crash Test/Simulation Comparisons

Occupant Safety Indexes	Median Barrier			Roadside Barrier		
	Test	Simulation	Error (%)	Test	Simulation	Error (%)
THIV (km/h)	23.3	23.8	2.0	30.9	30.2	-2.3
PHD (g)	7.9	8.0	1.3	10.5	10.8	3.2

Comparison of the results of full-scale crash tests and simulation certified the analysis model, the computer simulation was conducted for various impact conditions. The simulation matrix was composed to understand the influence on the occupant safety by an increase/decrease of the impact vehicle weight, speed and angle.

In Table 10, the simulation result according to the impact vehicle weight changes for the simulation barriers is shown. Changes of THIV and PHD values are shown in Figures 11 and 12. THIV value of the median barrier was almost same, and in case of the roadside barrier, the THIV value tended to decrease according to the impact vehicle weight decline. PHD value of the median barrier tended to decrease, and in case of the roadside barrier, the PHD value was irregular according to the impact vehicle weight decline. Generally, when the car impacts against the front side of the impact absorption facility, it does not give a good effect upon the occupant safety due to an increase of THIV value according to a decrease of the impact vehicle weight. In case of impacting to the side of the longitudinal barrier, it is estimated that a decrease of the impact vehicle weight does not affect on an increase of THIV vale related to yaw angle change according to the barrier hardness after the impact. To understand an influence of the impact vehicle weight change on the occupant safety, simulation for various impact vehicle weight changes by impact angles and researches through the full-scale crash test are needed. Until the research results in much wider ranges, it is estimated that the less weighted car should be selected as the impact vehicle by the traditional method for the occupant safety.

Table 10. Simulation Result According to Weight Change of Impact Vehicle

Barriers	Impact condition			THIV (km/h)	PHD (g)
	Impact Vehicle(kg)	Impact Speed(km/h)	Impact Angle(deg.)		
Domestic standard				≤33.0	≤20.0
Median	1300	120	20	30.0	19.0
Roadside				41.9	10.2
Median	1100	120	20	27.0	10.4
Roadside				31.2	26.0
Median	900	120	20	29.3	9.3
Roadside				32.3	14.7

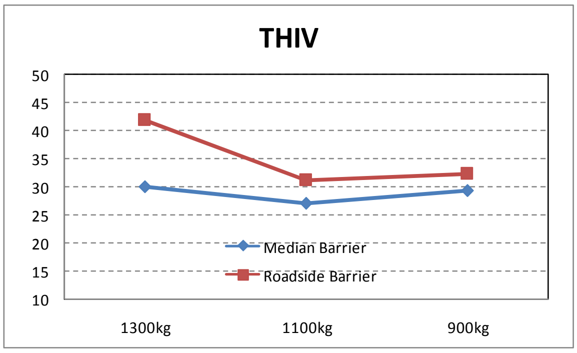

Figure 11. THIV Changes According to Impact Vehicle Weight

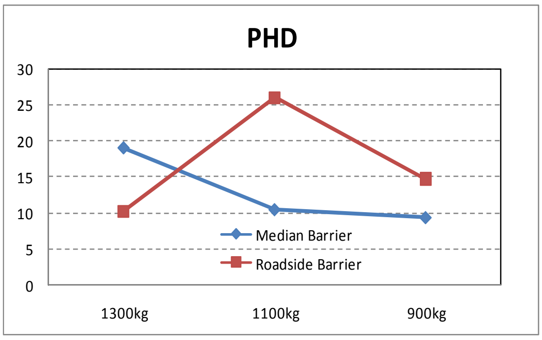

Figure 12. PHD Changes According to Impact Vehicle Weight

Table 11 shows a result of simulation with the maximum impact speed, and changes of THIV and PHD values are shown in Figures 13 and 14. In case of the median barrier, THIV value was 6.8% increased according to 20% increase of the impact speed, and PHD value was 113% increased. In case of the roadside barrier, THIV value was 38.7% increased according to 20% increase of the impact speed, and PHD value was 27.6% decreased. It is estimated that PHD value is increased in case of the concrete median barrier with the stronger hardness, and THIV value is increased in the roadside barrier with larger softness.

Table 11. Simulation Result According to Impact Speed Changes

Barriers	Impact condition			THIV (km/h)	PHD (g)
	Impact Vehicle(kg)	Impact Speed(km/h)	Impact angle(deg.)		
Domestic standard				≤33.0	≤20.0
Median	1300	100	20	28.1	8.9
Roadside				30.2	13.9
Median	1300	110	20	27.8	14.7
Roadside				31.3	14.3
Median	1300	120	20	30.0	19.0
Roadside				41.9	10.2

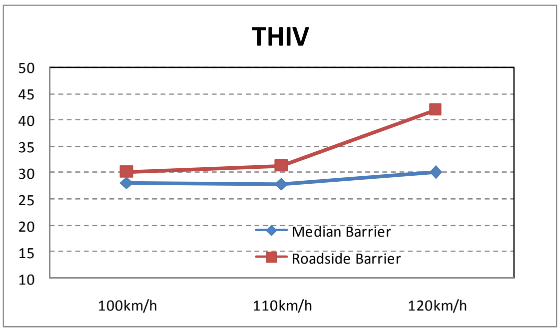

Figure 13. THIV Change According to Impact Speed Changes

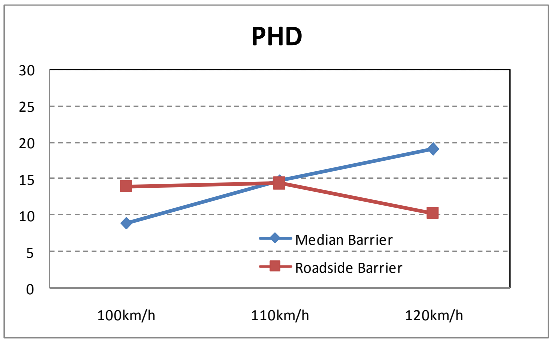

Figure 14. PHD Change According to Impact Speed Changes

Table 12 shows the result of simulation by changing the impact angles for the barrier in order to understand the influence on the occupant safety by the impact angle. Figures 15 and 16 show THIV and PHD value changes. In case of the median barrier, for 10° increase of the impact angle, THIV value was 53.9% increased, and 82.6% increase of the PHD value. In case of the roadside barrier, THIV value was 33.4% increased, and 74.3% increase of the PHD value.

The simulation configurations of the SMART highway impact condition are shown in Figures 17 and 18. From the simulation result of the SMART highway impact condition in Table 12, the performance of the median and roadside barriers on the existing domestic maximum performance level is under the standard value. Considering the limitation of the simulation for the case of median barrier, it could meet the suggested SMART highway impact conditions.

Application of the suggested SMART highway impact conditions for the final performance evaluation of existing median and roadside barriers, full-scale crash tests are needed. However, to minimize the degree of damage for the SMART highway's punctuality and safety after car-barrier collisions, development of new high-performance longitudinal barriers with enough safety rate are required.

Table 12. Simulation Result According to Impact Angle Changes

Barriers	Impact condition			THIV (km/h)	PHD (g)
	Impact Vehicle(kg)	Impact Speed(km/h)	Impact Angle(deg.)		
Domestic Standard				≤33.0	≤20.0
Median	900	120	15	21.9	9.2
Roadside				27.9	11.3
Median	900	120	20	29.3	9.3
Roadside				32.3	14.7
Median	900	120	25	33.7	16.8
Roadside				37.3	19.7

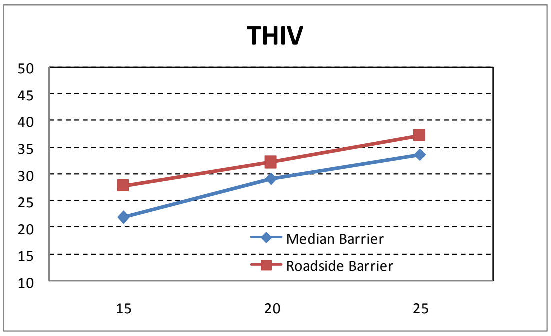

Figure 15. THIV Change according to the Impact Angle Changes

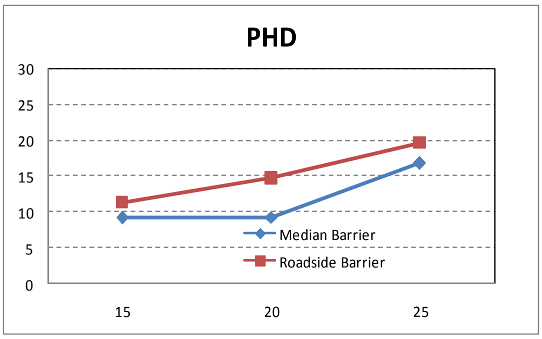

Figure 16. PHD Change according to the Impact Angle Changes

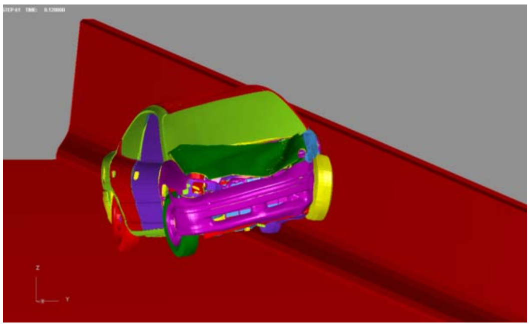
Figure 17. Simulation of the Median Barrier

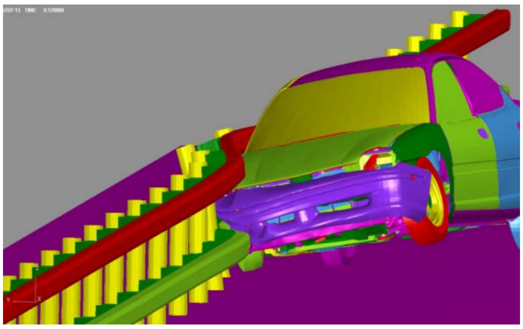
Figure 18. Simulation of the Roadside Barrier

5. Conclusion

From the investigated result of the relative impact condition domestic and international to minimize the degree of damage for the SMART highway's punctuality and safety after car-barrier collisions, the driving characteristics of SMART highway has not been considered. Through sales volume by weights of the domestic cars and research, a 900kg weighted passenger car was selected for the SMART highway impact vehicle to include 92.5% safety of the passenger car. By research of the distribution of the existing accident impact speed on an express highway, the distribution of the SMART highway accident impact speed was estimated. The suitable impact speed was confirmed as 120km/h for SMART highway including 70% accumulated accident impact speed from the estimated accident impact speed distribution. The SMART highway impact angle was suggested as 25°including 98% of the accident impact angle.

A simulation was conducted by the impact vehicle's weight, speed and angle with the highest performance facilities among the existing domestic very high leveled median and roadside barriers in order to evaluate the effect on occupant safety for the impact condition of the suggested SMART highway longitudinal barriers. From the analyzed result, both of THIV and PHD values were increased in the median barrier for the impact speed, especially the PHD value was largely increased. In the roadside barrier, the THIV value was largely increased and little decrease of the PHD value. For the impact angle, both of THIV and PHD values were largely increased. For longitudinal barriers, an influence on the occupant safety by the impact vehicle weight changes was not exactly understood. To understand the influence on the occupant safety by the impact vehicle weight changes, researches of more various simulations and full-scale crash tests are required. Through the analysis of the result, the researchers were able to realize the suggested SMART highway impact condition as a condition raised considerably compared to the existing standard. The existing domestic highest-performance medium and roadside barriers could not satisfy the suggested impact condition. New high-performance longitudinal barriers are required to minimize the degree of damage for the SMART highway's punctuality and safety after car-barrier collisions.

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